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Analyses of Mental Spatial Transformations during Early Design Conception

Experiments with the MindYourEEG Framework

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ABSTRACT

With an EEG based brain-computer interface as a supporting framework, we are conducting experiments on the role of object-based mental spatial transformations with the primitive operations of object *rotation, translation, scaling*, and *perspective shift* during a spatial design task. The scope of our experiments includes architecture design conception and refinement performed during early *sketching* and *desk-crit* sessions.

Our experiments focus on the use of motion imagery as a control mechanism classified through one or more machine learning techniques (e.g., multi-layer perceptrons, support vector machines). EEG data provides information on the internal state of the user: (a). patterns from the motor cortex characterise the real and imagined motion of body parts, (sometimes) including the direction of motion; (b). steady-state visual evoked response potentials provide visual spatial focus and attention data, in combination with eye-tracking and smart displays formatted to elicit unique responses (e.g., updating at different frequencies, strategic highlighting). We focus on distributed patterns rather than singular locations, although some of these may be generated only locally. As a first study, we are investigating the effect of the motion imagery control on the execution of spatial transformations. The experimental setup consist of a series of tasks with increasing complexity using the basic spatial transformations to be identified and applied. With these operators, we analyse how users adjust objects through the environment to the destination, the order, and the efficacy with which tasks are accomplished.

The experiments are conducted in the context of MindYourEEG, a work-in-progress extension of the BCI2000 framework, being developed as computational platform for empirical studies, experimental analyses of machine learning algorithms, and enabling the use of inexpensive as well as high-end EEG devices for human-computer interaction. MindYourEEG is being specialised as an experimental and analytical aid for spatial design domains requiring human-centred natural interaction capabilities. MindYourEEG aims to also function as a control device for design tasks without necessitating physical interaction – this is being done to enable natural control and placement of objects and environments in virtual spaces.

The study is situated in the context of our research in Project DesignSpace, which investigates the cognitive and computational foundations of next-generation design systems where the human-centred modalities of spatial cognition (e.g., perception, motion) constitute the fundamental building blocks. The results of these experiments guide the usability and interaction design considerations for such systems, where natural interaction capabilities for design manipulation and exploration are critical.

ANFA 2012 PARTICIPATION. *We propose to demonstrate the broader agenda of our research by a presentation, as well as deliver a demonstration during the poster session.*

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Daniel Michler holds Bachelor's degrees in Computer Science and Psychology from the University of Kentucky. He is now a computer science Masters student at Kentucky but presently based at the University of Bremen, Germany with the support of a joint US NSF and German DFG International Collaboration Program between the University of Kentucky (Professor Judith Goldsmith) and the University of Bremen (Dr. Mehul Bhatt). Currently he is working on his thesis, the MindYourEEG experimental framework, for easy construction, testing, and experimentation of EEG-based brain-computer interface systems in spatial design.

Mehul Bhatt is based at the Cognitive Systems (CoSy) research group within the Faculty of Informatics at the University of Bremen, Germany. He is also a member and principal investigator within the Spatial Cognition Center (SFB/TR 8) hosted between the Universities of Bremen and Freiburg, Germany. Mehul holds doctorate (computer science) and masters (IT) degrees from La Trobe University (Australia), and a bachelors degree in commerce and economics from (NM College) Mumbai University (India). He has been a recipient of the Alexander von Humboldt Fellowship (Germany), a German Academic Exchange Service (DAAD) fellowship, and an Australian Postgraduate Award (APA). Mehul's research and publications encompass the areas of spatial cognition, spatio-temporal reasoning, commonsense and non-monotonic reasoning as applicable to space, actions & change, applied ontology, and distributed systems. By these basic works, he address applications in a range of assistive technologies including the domains of design computing & computational design analyses, spatial design, cognitive robotics, geographic information systems, and medical information systems. Mehul Bhatt has been a co-organizer / editor of specialized workshops / publications in the area of spatial representation and reasoning, spatio-temporal dynamics, ambient intelligence and smart environments, and spatial design for architecture.

Holger Schultheis received masters' degrees in psychology and computer science from Saarland University in 2004 and a PhD degree in computer science from the University of Bremen in 2009. Currently he is principal investigator of the project R1-[ImageSpace] of the SFB/TR 8 Spatial Cognition. Combining experimental and computational approaches his research is concerned with gaining a deeper understanding of the mechanisms underlying human cognition and employing the gained insights to improve human-computer collaborative systems. The main focus of his research comprises various aspects of spatial cognition (e.g., perspective taking, mental spatial representations,

spatial language), mechanisms of associative learning, and techniques for building and evaluating computational cognitive models.